US patent 6,541,152 shows a different design also utilizing an insulating cup at the bottom and it has the same problem of decreasing useful cell volume and requires the handling of two separate material parts.

US patent 6,270,833 does not use any cup but the separator is made longer than the required useful length in the cell, the windings of the cylindrical separator body are bound together with a binder, and the extended portion is first pushed inwardly by a tool moving normal to the cylinder axis then folded back to close the initially open end. The folded and closed separator forms a self containing unit that should then be inserted into the cell. The smooth insertion requires a small clearance between the inner diameter of the cathode rings and the separator, which could increase cell resistance. The closing operation of the bottom part is complicated and requires movements in different directions, and problems can arise by the inevitable appearance of wrinkles.

US patent 6,035,518 describes a different method of making the separator, in which the separator material is wound around a mandrel and the winding is kept on the mandrel by a vacuum, and the separator does not constitute a self-containing unit, it should be guided until insertion into the semi-finished cell, wherein the winding tries to open up and fill the whole available space. While the idea of guiding the separator until insertion into the cell is preferable, the key problem, i.e. the closing of the bottom is solved here by the application of a hot melt sealant to fill the cell bottom including the bottom region of the separator. The presence of a sealant at the active lower region of the separator also decreases the available useful cell volume.

Japanese patent publication Sho58-82465 published on May 18, 1983 describes a method for making the separator, in which a multi-layered separator sheet material is wound around a core so that the bottom part of the wounded separator sheets extends out of the core along a predetermined length, then during rotation of the core and of the sheet material thereon the extended portion is contacted with a water wet felt to soak the sheet material with water and make it softer, and this soft extended part is inserted in a die to close the bottom part and in a further step the closed bottom part is heat-dried in a further tool. This method could not provide a wrinkle-free and perfect bottom closure, because the

rotating wet extended separator bottom part was moved axially in the die and first the end portion of the sheet got into contact with the die, and during the further downward movement of the rotating cylinder, wrinkles were formed and the soft wet material could not take a precise form. The wetting with a wet felt could not result in an evenly distributed and controlled amount of water in the whole area of this extended portion.

An improvement of the aforementioned method was published in Japanese patent publication Hei6-35662, wherein the disadvantages of the previously mentioned method were seen in the increased thickness of the curled bottom part. In the improvement cut slits were made in the extending bottom end of the multi-layered separator sheet material before the sheet material was wound around the core to remove a portion of the excess material from this bottom part, then practically the same steps were carried out as in the previous method, i.e. wetting and curling the bottom part by pushing the same in a die in vertical direction followed by a heat drying. In this method owing to the removal of a portion of the separator material the thickness was reduced, however, the separator bottom part was not securely closed and there was a need of inserting a separate closing cup in the interior of the bottom part of the separator (element 64 in Fig. 5 of the publication). The presence of this cup decreases the active volume of the cell interior and its placement requires a further step in the manufacturing process.

A further problem characteristic to separators used for secondary cells lie in that often a laminated structure should be used, since in case of secondary cells a thin semi permeable membrane layer, such as a cellophane layer should be provided. Two or more layered laminates are expensive and adhesives used to affix the layers contribute to higher internal resistance.

There is a further issue concerning separators that concern the need of synchronization with the general cell manufacturing process. State of the art processes produce at high speeds of 600 to 1200 parts per minute, and this high speed favors or requires easy to use technologies that can fit into the manufacturing line, rather than preparation of off-line, pre-fabricated separators, which can cause problems from additional handling.

Object of the Invention

The primary object of the invention is to enable maximum utilization of available cell volume. A further object is the combination of the unfolding nature of the guided separator as taught in the above referred US patent 6,035,518 with the reliable establishment of a closed bottom that does not require the application of a sealant in the useful cell area, or overcoming the disadvantages of the methods described in the cited Japanese publications. Yet another object of the invention is to provide on-line adjustments of the sheet material length without the changes of any hardware components. A different object is to provide a separator that does not require the use of a laminate sheet if a multi-layered structure is required e.g. for secondary cells. A still further object is to provide a method that is simple, easy to make and which can provide synchronization with the cell manufacturing process.

Summary of the invention

These objects have been met by providing a separator and a method for making the same as defined and described in the attached claims.

Description of the drawings

The invention will now be described in connection with preferable embodiments thereof, wherein reference will be made to the accompanying drawings. In the drawing:

Fig.1 shows the schematic top view of the sheet feeding station;

Fig.1a is the simplified elevation view of a part of Fig. 1;

Fig.2 is a similar view as Fig. 1 adapted for feeding two sheets;